CHAPTER 5

To study the sensory quality of bottle gourd juice (BGJ) samples, obtained from microwave-ultrasound based combined treatment

5.1. Introduction

The demands for vegetable and fruit juice are increasing in the present day global market. Today consumers understand the relationship of how the intake of bioactive compounds can help in maintaining a good health and wellbeing [27]. Vegetable and fruit juice provide vital supplements into the daily nutrition requirements [17] as vegetables and fruits juice contains bioactive compounds like phenolics, alkaloids and terpenoids [27]. Bottle gourd is a vegetable of the cucurbitaceae family commonly grown in India. Bottle gourd has been mentioned in Indian ayurvedic medicine as an important natural product against various chronic disorders [25]. The benefits of bottle gourd in different ailments are mainly due to the presence of its bioactive compounds like ascorbic acid, flavonoids, terpenoids and phenolics which further contribute into the total natural antioxidants [21]. Bottle gourd has been approved as a vegetable which is rich in vitamin B complex and choline with fair amount of vitamin C [5]. Fresh and tender bottle gourds are used for juice extraction and for consumption as vegetables [5]. Bottle gourd juice possesses cardio protective activity along with its ability to maintain the alkaline reserve of human body [31]. Though bottle gourd juice contains many health beneficial properties, it is also rich in nutrients required for microbial growth and provides suitable pH and water activity for microorganism growth [2]. As a result, the safety of bottle gourd juice consumption and its storage is a challenge. [5] reported thermal treatment of bottle gourd juice within the temperature range of 75-121ºC for treatment time of 7-30 min. Thermal treatments, however, tends to damage the nutritional and bioactive compounds of a natural product [10]. The demand of consumers for nutritious and minimally processed food has led to the development of different mild or non-thermal technologies. Microwave radiation has been used in pasteurization as an alternative to conventional long thermal treatments [10]. Microwaves penetrate and interact with the water molecules present in the food, due to which energy dissipation occurs and food is heated rapidly. The lethality of microwaves over microbial growth has been studied in many studies [7]. Ultrasound is another alternative which is frequently studied for its abilities to decrease microbial growth [1] without decreasing the bioactive compound present in the natural product [22,30]. Ultrasound has been used in sterilization and extraction process, which ultimately reduces treatment times and operates the process with improved efficiency [24,29]. Ultrasound can be made more effective if it is combined with other techniques like UV, high pressure and microwave. With the nutritive property of a food product, the sensory property is also important for consumer's satisfaction of the product [11]. In the works of [15], sensory evaluation has been explained as an important scientific discipline to analyse characteristics of foods. Sensory study is very important for development and selection among similar foods [16]. Sensory evaluation comprises of methods for interpreting human responses to different stimulus that is developed due to different senses [3]. There has been a mixed report about microwave pasteurization on the sensory properties of a food product. In the works of [12], there was no difference between the microwave pasteurized sample and the fresh samples of tamarind beverage, but microwave pasteurization did affect the sensory properties of a formulated beverage (pineapple, *nopal*, guava, and lemon juice). The importance of microwave treatment in retaining the sensory quality of beverage from natural product was reported by [9]. Ultrasound processed samples were reported to receive lower sensory scores when compared with untreated samples [13]. But ultrasound treated samples have greater sensory value then thermal treated samples [17]. Sensory attributes of the food products are generally performed based on the scores given by a trained panel. An individual lacking appropriate training to assess the linguistic parameter frequently tends to be very dubious. Another huge restriction of customer sensory assessment is its abstract nature. Based on this aspect, fuzzy logic can be applied for the evaluation of sensory scores.

The importance of microwave treatment in retaining the sensory quality of beverage from natural product was reported by [9]. There were mixed reports of the sensory qualities of ultrasound treated samples. Ultrasound processed samples were reported to receive lower sensory scores when compared with untreated samples [13]. Some studies also reported about ultrasound treated samples to have greater sensory value then thermal treated samples [17]. So, it was necessary to perform a sensory study in the present microwave and ultrasound treated sample. Sensory attributes of the food products are generally performed based on the scores given by a trained panel. An individual lacking appropriate training to assess the linguistic parameter frequently tends to be very dubious. There can also be another huge restriction of customer sensory assessment because of its abstract nature. Thus, to avoid certain problems which arises in taking a decision during the sensory analysis, fuzzy logic can be applied for the evaluation of sensory scores.

This logical apparatus can be utilized to appoint particular codes for all the linguistic parameters. After a progression of numerical control, every item is allotted a solitary score. Considering the choices of the panellists, the scores are further defuzzified to get the semantic term comparing to the score.

Henceforth, fuzzy logic eliminates emotion, accordingly, giving exact outcomes with considerable repeatability. Likewise, it addresses another downside of the typical assessment system. In conventional sensory evaluation, the board should have a significant number of individuals. Nonetheless, with the usage of fuzzy logic, a lesser number of specialists is sufficient to create dependable outcomes. A positioning of the general significance of different quality parameters of the juice is additionally considered in this investigation. Consequently, the outcome of fuzzy logic not only just considers the specialists' assessment with respect to the general nature of the item but also consider their perspectives regarding the overall meaning of the distinctive quality ascribes. All the referenced advantages legitimize fuzzy logic to be the best technique for making a decision about the sensorial agreeableness of the food products [26]. In the present study the effect of the combined microwave and ultrasound pasteurization on the sensory properties of bottle gourd juice was examined using fuzzy logic and proportional odd modelling approaches.

5.2. Materials and methods

5.2.1. Materials

Fresh and tender bottle gourds were procured for juice extraction from a vegetable grower’s nursery of Tezpur, Assam (India). The sample was identified taxonomically (Accession No: GUBH18494) in the Gauhati University, Assam, India.

5.2.2. Bottle gourd juice (BGJ) preparation

Bottle gourds were washed and wiped with a absorbent paper, stripped and cut into uniform shapes (2×2×2 cm). Based on the method described by [5,6] Bhat et al. (2017), blanching was performed with the help of distilled water (85ºC for 5 min). The sample was allowed to cool promptly with the assistance of chilled water as soon as the blanching was done. The BGJ was extracted from the sample with the help of the domestically used grinder (Bajaj Majesty 1.5 L JX4 Juicer Mixer Grinder). The juice was further centrifuged (Eppendorf Centrifuge 5430 R, Germany) at 5,000 rpm with duration of 15 min and filtered with the help of Whatman paper (No1) to eliminate the debris and suspended particles.

5.2.3. Microwave-ultrasound based combined treatment of the BGJ

The BGJ was processed, using microwave temperature of 70˚C, microwave yield power of 750 W, ultrasound amplitude of 80%, and ultrasound exposure for 15 min [10]. The BGJ (100 ml) sample was initially treated in the microwave system (Milestone Technologies, NEOS GR Microwave Extraction System) at desired temperature of 70˚C for 20 s. The microwave treated samples were then moved to ultrasound system aseptically. The samples were chilled and the temperature was brought down to 20ºC in the ultrasound based system (QsonicaLLC.Q700-220) (Probe sonicator) with cold water moving in circular motion [22]. With amplitude of 80% (Frequency 20 KHz) and process time of 15 min, the ultra-sonication was performed. The temperature of the samples was not allowed to rise above 30ºC.

5.2.4. Conventional processing of BGJ

The conventional processing of the BGJ was performed at 75°C for 10 min [5,6], using hot water bath (Equitron, India). The monitoring of the sample temperature was performed using an infrared digital thermometer (Bexco, South Korea).

5.2.5. Sensory analysis of BGJ

Three different samples viz., raw (sample 1), conventional (sample 2) and microwave-ultrasound based samples (sample 3) were considered for the sensory evaluation. A panel of twenty-five (25) members were selected for assessing successive BGJ. The panellists were familiarized with various terminologies of sensory viz.,color, taste, mouthfeel and aroma along with scoring methods before the evaluation. During the evaluation of BGJ samples, the panellists gave marks based on the five point hedonic scale. The evaluation for each sample was made rapidly but not quickly. The panellists were instructed to wash their mouth with water after tasting of each sample. Based on the scale of "Not satisfactory (NS)", "Fair (FA)", "Medium (ME)", "Good (GD)" or "Excellent (EX)", the samples were evaluated. The scores were analysed using fuzzy logic and proportional odd modelling (POM) based hybrid approach [14,19,23].

5.2.6. Application of fuzzy logic for the analysis

Linguistic data obtained from the sensory evaluation were utilized by this method. On the basis of triangular fuzzy membership distribution, the ranking of the samples was done [28]. During the fuzzy analysis, triplet values were obtained from the initial scores given by the panellists.

In order to estimate similarity values, the triplets were utilized, and ultimate ranking of the samples was done. For the sensory analysis on the basis of fuzzy logic, following steps were performed: **1.** Sensory scales associated triplets determination; **2.** Triplets estimation in context to samples and all attributes; **3.** Triplets estimation as associated with relative weightage of the traits; 4. Overall sensory scores (OSS) based triplets estimation; 5. Overall membership function (OMF) estimation for the sensory scores; 6. Similarity value estimation for various samples and quality attributes; 7. Final Ranking of the samples and their associated attributes.

All the above-mentioned steps were performed in MATLAB R2015a (Mathworks, Natick, MA, USA) with the help of developed fuzzy logic code. A set of three numbers namely triplets were used for delineating triangular membership function distribution pattern of 5-point hedonic scales. In combination of "NS (0, 0, 25)", "FA" (25, 25, 25)," "MD" (50, 25, 25)" "GD" (75, 25, 25)" and "EX" (100, 25, 0)", the distribution pattern of 5-point sensory scores were composed. In context to triplets associated with triangular function, coordinates of abscissa with membership function 1 signify the first number of the triplets as mentioned previously within the parenthesis, whereas by taking distance to left and right of the first number along with the consideration of zero value of the membership function, second and third numbers of the triplets were designated [28].

5.2.7. Triplets of sensory scores

The estimation of the triplets of various samples and quality attributes was done based on equation 5.1:

$$S_jC = \frac{N_1(0\ 0\ 25)+N_2(25\ 25\ 25)+N_3(50\ 25\ 25)+N_4(75\ 25\ 25)+N_5(100\ 25\ 0)}{(N_1+N_2+N_3+N_4+N_5)}$$

(5.1)

Where, $(N_1 + N_2 + N_3 + N_4 + N_5)$ stand for total number of panellists, C refers to color attribute, the subscript "j" stands for the number of samples, while N_1, N_2, N_3, N_4 and N_5 are the number of panellists for the derivation of score under each quality attribute of every sample.

Based on the calculated triplets, the relative weightage of the scores for each category was estimated by the equation 5.2:

$$S_jO = S_jC \times QC_{rel} + S_jT \times QT_{rel} + S_jM \times QM_{rel} + S_jA \times QA_{rel}$$
(5.2)

Where, C stands for color, T stands for taste, A stands for aroma, M stands for mouth feel, sample number is represented by subscript "j". QC_{rel}, QA_{rel}, QT_{rel}, and QM_{rel}stand for triplets associated with the relative weightage of the quality attribute [23].

5.2.8. Membership function assessment based on standard fuzzy scale (SFS)

Based on a set of 10 numbers (equation 5.3), the membership values for each triangular distribution were estimated. The standard scale for the estimation denotes as F1, F2, F3, F4, F5 and F6. The six-point scales stand for not satisfactory (NS) as F1, fair (FA) as F2, satisfactory (SA) as F3, good (GD) as F4, very good (VG) as F5 and excellent (EX) as F6.

$NS = (SC_1, SC_2, 0, 0, 0, 0, 0, 0, 0, 0)$

$FA = (SC_2, SC_1, SC_1, SC_2, 0, 0, 0, 0, 0, 0)$

$SA=(0, 0, SC_2, SC_1, SC_1, SC_2, 0, 0, 0, 0)$ (5.3)

$GD = (0, 0, 0, 0, SC_2, SC_1, SC_1, SC_2, 0, 0)$

$VG = (0, 0, 0, 0, 0, 0, SC_2, SC_1, SC_1, SC_2)$

$EX = (0, 0, 0, 0, 0, 0, 0, 0, SC_2, SC_1)$

Here, SC_1 refers to 1 and SC_2 refers to 0.5

5.2.9. Estimation of overall membership function (OMF)

The OMF of the samples was determined by using one of the following equations given below (equation 5.4)

$$B_x = \frac{x - (e - f)}{f}, \text{for } (e - f) < x < e$$

$$B_x = \frac{(e + g) - x}{g}, \text{for } e < x < (e + g)$$

$$B_x = 1 \text{ for } x = e \tag{5.4}$$

$$B_x = 0 \text{ for all other variables of } x$$

Here, B_x refers to the value of sensory score's membership function that are estimated at x = 0 to 100, membership values of the sensory overall scores are represented by e, f and g, x which refers to a set with ten numbers with intervals of 10 starting from 0 < x < 10 to 90 < x < 100 [28].

5.2.10. Estimation of the similarity values (SV) and ranking of the samples

The SV of the samples were calculated with regard to the B values obtained by equation (5.4). The mathematical expression for the calculation of similarity values is given as follows (equation 5.5):

$$S_m(F, B) = \frac{F \times B'}{\mathrm{Max}(F \times F' \text{and } B \times B')} \tag{5.5}$$

Here, S_m stands for similarity value associated with particular sample, $F'$and B'refers transpose of F and B matrices, respectively. The SV obtained for each sample under each category and compared for the final ranking of the samples.

5.2.11. Hybridization of fuzzy logic and proportional odd modelling for the ranking of samples

Similarity values obtained for different samples were ranked on the basis of hybrid approach of fuzzy logic and proportional odd modelling. In order to formulate similarity values, fuzzy logic was implemented. For accurate and proper ranking of the samples, proportional odd modelling (POM) approach was applied during the analysis of the similarity values. In the present study the POM approach was implemented by using R software (R 3.4.1).

POM is a multivariate augmentation of generalized linear models, permitting the displaying of the probabilities related with every classification of reaction under the impacts of exogenous factors, including the linear factors. The consumer attitude was estimated based on the five-point hedonic scale. The scale was denoted as {1, 2, 3, 4, 5}, with ascending order of 1 <2 <3 <4 <5. The strategy of POM evaluates the probabilistic disposition of consumers by considering the impacts of the co-factors and non-quantifiable elements (panellist impact). In this context, the marginal probability (j = 1, 2, 3, 4, 5) is denoted as πj(x). In order to evaluate product acceptance for each category Y, the marginal probability was utilized [20,18,8]. For the j^{th} response category, the accumulated probabilities can be expressed by the following equation (5.6):

$$\gamma_j(X) = \pi_1(X) + \cdots + \pi_j(X)$$

(5.6)

On the basis of the accumulated probabilities, POM can be expressed by equation 7.

$$\ln[(\gamma_j(X))/(1 - \gamma_j(X))] = \lambda_j - (\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{p-1} X_{p-1})$$

(5.7)

Here, λ_j is the intercept, β_{p-1} represents slope and X_{p-1}represents covariable's vector (p stands for number of samples).

If,$\ln[(\gamma_j(X))/(1 - \gamma_j(X))] = L_j$, the proportional odd models for all the scales (j-1) can be given as follows.

$$L_1 = \lambda_1 - (\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{p-1} X_{p-1}) \quad (5.8)$$

$$L_2 = \lambda_2 - (\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{p-1} X_{p-1}) \quad (5.9)$$

$$L_3 = \lambda_3 - (\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{p-1} X_{p-1}) \quad (5.10)$$

$$L_4 = \lambda_4 - (\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{p-1} X_{p-1})$$
(5.11)

5.3. Results and Discussions

The BGJ samples viz., sample 1 (raw), sample 2 (conventionally treated) and sample 3 (microwave-ultrasound based combined treated) are presented in Figure.5.1. Sensory scores of BGJ samples for different quality attributes (QA) viz., C, A, T and M were obtained based on the scores of twenty-five judges as mentioned earlier. The sensory scores of the bottle gourd juice samples under different quality attributes are shown in Figure 5.2. During the evaluation, total three samples viz., sample 1, 2 and 3 were considered. The sensory scores for different QA of bottle gourd juice in general are represented in Figure. 5.3. The judgement of the quality attributes in general was done based on the four qualities attributes viz., C, A, T and M.

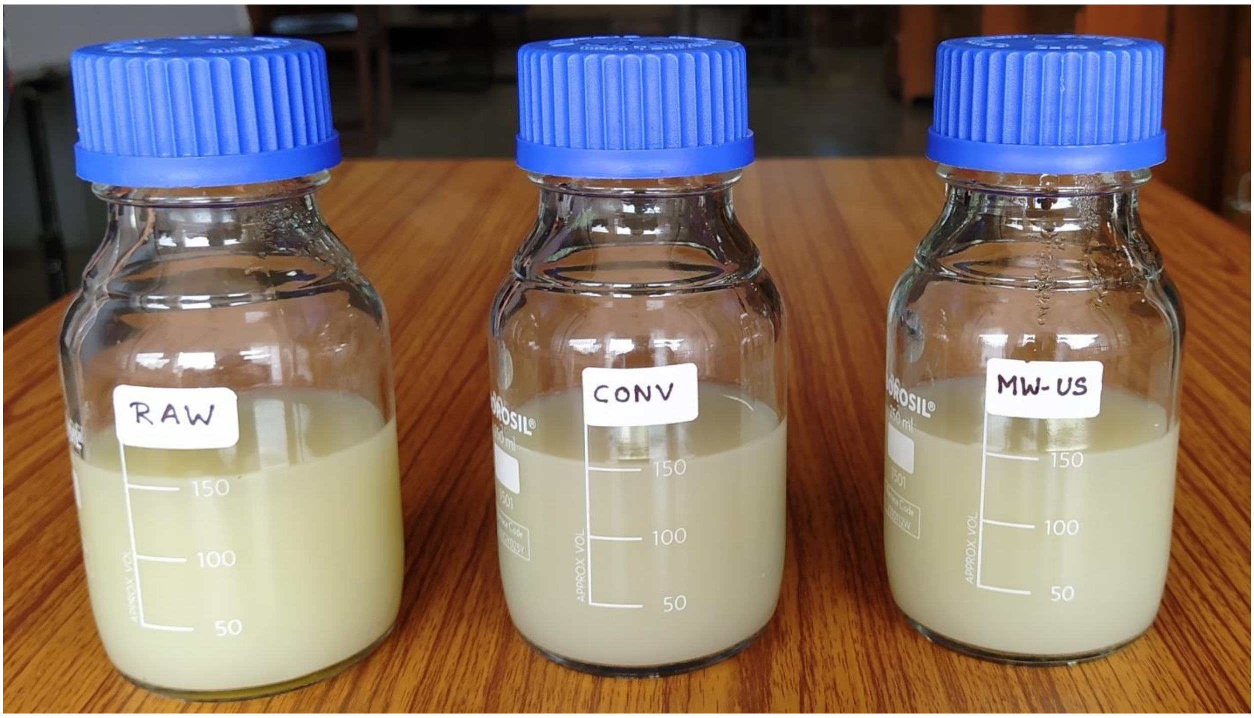

Figure 5.1: The BGJ samples viz., sample 1 (raw), sample 2 (conventionally treated) and sample 3 (microwave-ultrasound based combined treated)

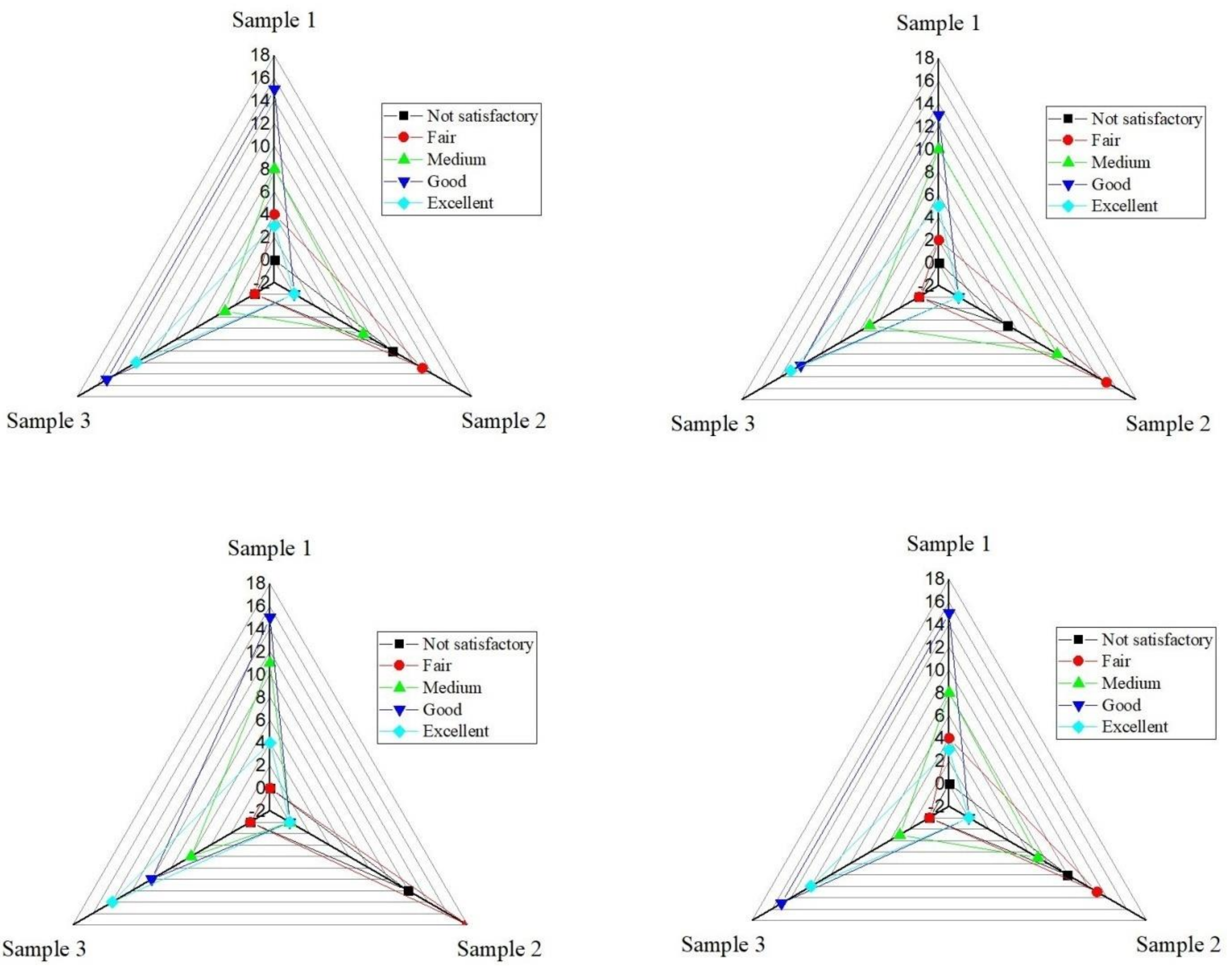

Figure 5.2: The sensory scores of the bottle gourd juice samples under different quality attributes

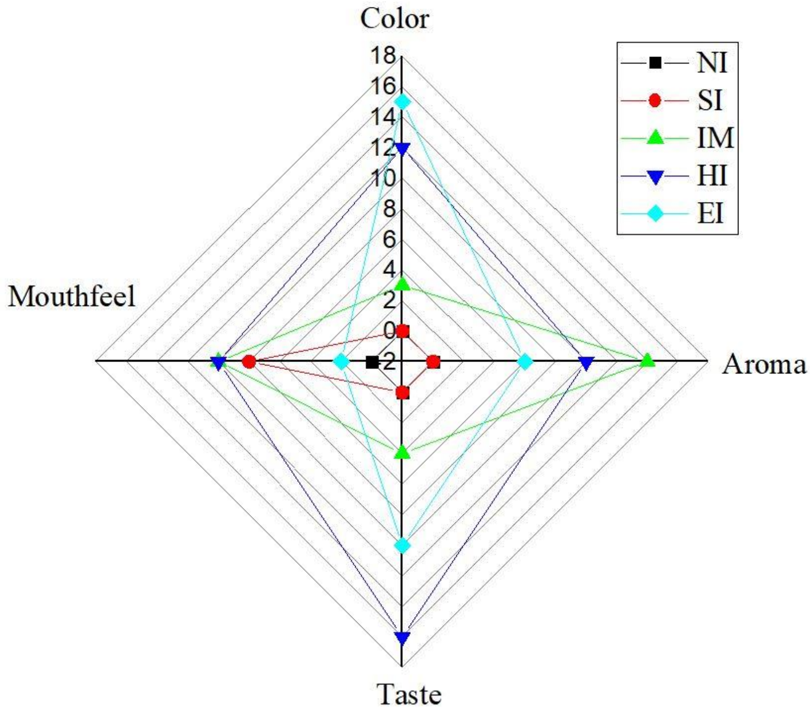

Figure 5.3: The sensory scores for different QA of bottle gourd juice in general

Table 5.1: Similarity values of bottle gourd juice samples and quality attributes in general

Scale factors	Sample 1	Sample 2	Sample 3	Scale factors	Color	Aroma	Taste	Mouthfeel
Not satisfactory	0.000	0.356	0.216	**Not at all Important**	0.00	0.30	0.28	0.31
Fair	0.087	0.692	0.139	**Somewhat important**	0.00	0.15	0.14	0.22
Satisfactory	0.358	0.581	0.203	**Necessary**	0.00	0.18	0.03	0.50
Good	0.653	0.166	0.446	**Important**	0.32	0.65	0.37	0.68
Very good	0.658	0.000	0.584	**Highly important**	0.92	0.53	0.70	0.24
Excellent	0.234	0.000	0.268	**Extremely important**	0.51	0.06	0.25	0.00

Table 5.2: Ranking of juice samples and quality attributes in general

<table>
<tr><th></th><th colspan="3">Coefficients</th><th></th><th colspan="3">Coefficients</th></tr>
<tr><th></th><th>Estimated value</th><th>Standard error</th><th>t value</th><th></th><th>Estimated Value</th><th>Standard error</th><th>t value</th></tr>
<tr><td>Sample 2</td><td>-2.809</td><td>2.132</td><td>-1.318</td><td>Taste</td><td>0.832</td><td>2.026</td><td>0.411</td></tr>
<tr><td>Sample 3</td><td>-0.213</td><td>1.875</td><td>-0.114</td><td>Color</td><td>2.295</td><td>2.126</td><td>1.079</td></tr>
<tr><td>Intercepts</td><td>Estimated value</td><td>Standard error</td><td>t value</td><td>Mouthfeel</td><td>-0.666</td><td>1.809</td><td>-0.368</td></tr>
<tr><td>1|2</td><td>-3.887</td><td>2.202</td><td>-1.765</td><td>Intercepts</td><td></td><td></td><td></td></tr>
<tr><td>2|3</td><td>-2.475</td><td>1.794</td><td>-1.380</td><td></td><td>Estimated Value</td><td>Standard error</td><td>t value</td></tr>
<tr><td>3|4</td><td>-1.133</td><td>1.429</td><td>-0.793</td><td>1|2</td><td>-1.833</td><td>1.626</td><td>-1.127</td></tr>
<tr><td>4|5</td><td>0.148</td><td>1.314</td><td>0.113</td><td>2|3</td><td>-1.273</td><td>1.502</td><td>-0.848</td></tr>
<tr><td>5|6</td><td>1.8366</td><td>1.7263</td><td>1.0639</td><td>3|4</td><td>-0.662</td><td>1.418</td><td>-0.467</td></tr>
<tr><td></td><td></td><td></td><td></td><td>4|5</td><td>0.825</td><td>1.422</td><td>0.580</td></tr>
<tr><td></td><td></td><td></td><td></td><td>5|6</td><td>3.117</td><td>1.930</td><td>1.615</td></tr>
</table>

5.3.1. Triplets of sensory scores for the various samples and QA

As a part of the sensory analysis based on fuzzy logic, triplet values were determined for all the mentioned samples and QA. In accordance with the five point hedonic scale, these values were estimated. Further, these values were determined on the basis of (a) sum of sensory scores; (b) sensory scores associated triplets and (c) number of judges [23]. In the present study, triplets were estimated for the above mentioned three samples and four quality attributes (color, aroma, taste and mouthfeel).

5.3.2. Estimation of OMF

Based on SFS, the OMF of the sensory scores for different BGJ samples were estimated. In accordance with the SFS, the F values were estimated in case of determining these membership functions. As mentioned earlier, NS (F1), FA (F2), SA (F3), GD (F4), VG (F5) and EX (F6) were considered as the six point SFS. On the other end, the six point scale for the sensory scores of QA in general were deemed as not at all necessary (F1), somewhat necessary (F2), necessary (F3), important (F4), highly important (F5) and extremely important (F6) [23].

5.3.3. SV of different samples and their associated QA

As the final step of the fuzzy logic analysis, SV were determined for both the samples and their QAs. The SV for the three samples were estimated on the basis of the member function. Table 5.2 represents the SV for the three juice samples (denoted as B1, B2 and B3). The mathematical expression as shown in equation 5 was implemented in case of estimating the similarity values [23].

Table 5.1 demonstrates the similarity values for the three types of BGJ samples. As shown in the results, higher acceptability of sample-1 can be revealed. Further from the ranking second position of sample 3 can also be observed. But, by comparing the similarity values in excellent scale, higher acceptability of sample 3 was observed, which is exactly opposite to the previous statement. Hence for sorting out this perplexing circumstance and also for stating comprehensive conclusion another analysis namely proportional odd modelling (POM) was done based on the similarity values. This particular approach is named as hybrid approach of fuzzy logic and proportional odd modelling (FL-POM). For the ranking of QA in general based on the SV (Table 5.1), similar approach of hybrid FL-POM was also implemented. This helped to state inclusive conclusion for the ranking of QA of the BGJ samples in general.

5.3.4. Hybrid FL-POM approach for the ranking of BGJ samples and their quality attributes

Hybrid FL-POM approach was applied for the ranking of three types of juice samples and their associated QA. Based on this approach, similarity values obtained from the results of fuzzy logic was used for the comprehensive ranking of both the samples and their quality attributes. The analysis was performed for three samples (sample-1, sample-2 and sample-3) and their associated QA viz., C, A, T and M. The results of POM for the ranking of samples are presented in Table 5.2. The estimated coefficients of POM in case of quality attributes in general are shown in Table 5.2. By comparing the estimated coefficients along with reference sample and attribute, the ranking of the BGJ samples can be written in the order of sample-1>sample-3>sample-2, whereas for their associated quality attributes the ranking can be written as C>T>A>M. Therefore, raw BGJ can be stated as the best sample followed by microwave-ultrasound treated one in the second rank. As for any juice sample pasteurized one is mainly preferred owing to its safety and longer shelf life and microwave-ultrasound treatment based BGJ can be stated as the best sample.

5.4. Conclusion

Sensory evaluation of BGJ samples, acquired from microwave-ultrasound based combined treatment was performed in this investigation. For the assessment raw (sample-1) and conventionally treated (sample-2) samples alongside microwave-ultrasound treated (sample-3) were considered. An innovative approach of hybrid fuzzy logic and proportional odd modelling (FL-POM) was implemented for the analysis of the sensory scores. From the results of fuzzy logic, the similarity values for the juice samples and their associated QA were resolved. These values were considered as input for hybridization with the POM approach. The assessed coefficients obtained from the results of POM were considered for the ranking of the samples and quality traits. The ranking of the BGJ samples was observed in the order of sample-1>sample-3>sample-2, while for their related quality credits the ranking was in the order of Color>Taste>Aroma>Mouth feel. The microwave-ultrasound treated BGJ was derived as the best sample as compared to the raw sample owing to its higher inclination and agreeableness.

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